Conference Volume | 5th Symposium for Research in Protected Areas 10 to 12 June 2013, Mittersill | pages 843 - 848

# Effects of gravel mining on the surface-active arthropod fauna of ephemeral gravel-bed stream valleys in the National Park Gesäuse (Styria, Austria)

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## Abstract

In the National Park Gesäuse (Austria, Styria), several tributaries of the Enns river are ephemeral streams that have accumulated large amounts of gravel in the broadened stretches of their valleys. In two of these valleys, gravel mining has been performed until recently. With the establishment of the National Park, these activities have been terminated and the gravel fields have been restored. It remains unclear, however, whether gravel mining has affected the surface arthropod assemblages and whether the restoration measures have re-established a natural arthropod community in those valleys.

A randomised, replicated, controlled study was performed between 4 May 2012 and 30 September 2012. In a BACI-type design, ten samplings areas were compared, with sites from impacted valleys and control valleys above, within and below the gravel extraction areas. Each sampling site was visited seven times; during each visit, arthropods were collected by hand catch for the duration of one hour. Additionally, environmental variables were recorded. The sampling visits were randomly allotted to the sampling areas; within the sampling areas, transect positions perpendicular to the stream channel were also located randomly.

Detrended Correspondence Analysis and Nonmetric Multidimensional Scaling showed a clear differentiation between the ephemeral gravel valleys and typical riverbanks of Johnsbach and Enns in the region. The gravel valleys showed an arthropod fauna impoverished in species numbers and dominated by a single species, the wolf spider *Pardosa saturatior*. Gravel valleys impacted by gravel mining showed a more diverse fauna with a higher proportion of trivial species and with assemblages that were more closely related to assemblages of banks and shores of perennial rivers. While the assemblages of the upstream areas were rather similar between impacted and control valleys, the lower valley stretches differed increasingly in their species composition towards the mouth of these valleys.

Comparison of a quality index calculated for the sampling areas showed lower values for the impacted areas, but the differences were not significant (ANOVA). It may be concluded that gravel mining has affected the assemblages of surface-active arthropods, but the changes are relatively small. Most of the typical species are still present in the valleys affected by gravel mining, which offers good prospects for the further restoration of these valleys. In summary, alpine gravel valleys with ephemeral streams appear to be a conspicuous yet poorly researched mountain habitat type with a distinct fauna of highly specialised species that are able to tolerate the harsh conditions between catastrophic inundation and dryness.

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## Keywords

Ephemeral streams, gravel mining, *Pardosa saturatior*, karst, multivariate ordination

## Introduction

Limestone and dolomite are rocks that are easily weathered. Their decomposition products – debris, scree and gravel – are important landform elements in calcareous mountain systems. The limestone material with its fractures, fissures and pores favours percolation and infiltration of large amounts of water. Mountain streams entering valleys filled up with calcareous sediments thus often disappear in the gravel bed and flow underground within the pore system. During periods of high precipitation, however, e.g. after snow melt, rainy periods or thunderstorms, the capacity of the pores might be exceeded and peaks of violent surface runoff may be generated. During such phases, large parts of the mountain valley may become flooded, the dramatically increased stream capacity may transport large amounts of material downstream and powerful erosion and sedimentation processes may substantially transform the entire streambed landscape.

With their alteration between the terrestrial and the aquatic phase, all types of floodplains represent challenging environments for surface-active arthropods. Species unable to withstand or to avoid the unsuitable phase cannot live in floodplain biotopes (ADIS & JUNK 2002), others require particular survival strategies to survive under such harsh conditions (ADIS 1992). Among the various kinds of floodplains, ephemeral mountain stream valleys are probably those with the most extreme conditions. During large parts of the year, the valleys are completely dry, typically lack any vegetation and are nearly sterile, except for small amounts of organic material deposited in some pockets of low flow velocity. Ephemeral streams lack the resource supply of ordinary perennial streams, which continuously deposit organic material and aquatic organisms along their beaches and also provide humidity and water all year round (HERING & PLACHTER 1997). During flash floods, arthropods in karst valleys are not only affected by high water levels and large-scale inundation of their terrestrial habitats, but also by high flow velocity and extremely high mechanical disturbance, with large amounts of rock and gravel material moving downstream with the water flow.

Most research on ephemeral streams seems to have been focused on aquifers in arid, semiarid and Mediterranean-type climates (e. g. CAMARASA BELMONTE & SEGURA BELTRÁN 2001). Information on the ecological conditions and the assemblages of ephemeral karst streams seems to be very limited in general (MEYER & MEYER 2000), and in particular on karst streams from alpine regions.

In the National Park Gesäuse in the Austrian Alps, several side valleys of the Johnsbach and Enns river systems area sediment troughs with stream channels lying dry throughout the year and surface runoff only during extreme weather events. Until recently, two of these valleys have been used for gravel mining and asphalt production, but these uses have been terminated with the establishment of the National Park. In both valleys, production facilities have been de-assembled and removed, and the surface has been restored (HOLZINGER et al. 2011). It is not clearhowever, to what extent the mining activities have affected the original surface-active arthropod assemblages of those ephemeral stream valleys and whether the restoration measures have successfully re-established the typical environmental conditions and the associated arthropod assemblages of the gravel fields. Thus, the study presented here had two goals: (1) Tocharacterise and delineate the arthropod assemblages of the karst valleys in comparison with ordinary riverbank assemblages of the Johnsbach and Enns rivers. (2) To assess the effect of the gravel mining impact on the arthropod assemblages, measured by multivariate ordination techniques and two assemblage quality indices.

## Material & Methods

The study compared ten study areas in the National Park Gesäuse from four valley systems (Weißenbachlgraben, Haindlkar, Gsenggraben and Kainzenalplgraben) situated in altitudes between 500 and 800 m with regard to their arthropod assemblages in a BACI-type sampling design (UNDERWOOD 1996). Six of the ten sampling areas were located in valleys impacted by gravel mining; four were situated in control valleys. Within each impacted valley, one sampling area was located upstream, one within, and one downstream of the former gravel mining area. Areas in control valleys were at corresponding altitudes as their counterparts in the impacted valleys. Within each of the sampling areas, seven sampling transects perpendicular to the channel direction were located using random distances from a pre-defined reference point at the lower border of the sampling area. The sampling sequence of all 70 transects was randomised to avoid any bias due to season, weather conditions or post-inundation stage. Each transect was examined for one hour by turning stones and collecting all surface-active arthropods belonging to ground beetles (Carabidae), rove beetles (Staphylinidae), spiders (Araneae), millipedes (Diplopoda and Chilopoda) and woodlice (Isopoda terrestrial) with an aspirator. The material was stored in a mixture of 80% alcohol and diluted acetic acid for later identification in the laboratory. Individuals were typicallyidentified to the species level, however, only some of the juvenile spiders could be assigned to species by comparing them with adults sampled at the same locality; others could only be identified to the family level.

The assemblages were analysed using the ordination techniques Detrended Correspondence Analysis and Nonmetric Multidimensional Scaling, the latter being based on the Renkonen similarity index (LEGENDRE & LEGENDRE 1998). The relationship between assemblages from the ten sampling areas, assemblages from two reference stream bank sites sampled for comparison and assemblages from two earlier studies conducted at the Johnsbach and Enns river banks (BRANDL 2005, FRITZE et al. 2007) was visualised in ordination plots. For DCA, the software CANOCO 4.5 was used (TER BRAAK & ŠMILAUER 1998), for NMDS the procedure PROXSCAL 1.0 in SPSS 10.0.5 was applied (SPSS, Inc.). Renkonen similarity numbers were calculated using an Excel (Microsoft Corp.) spreadsheet with array formulas.

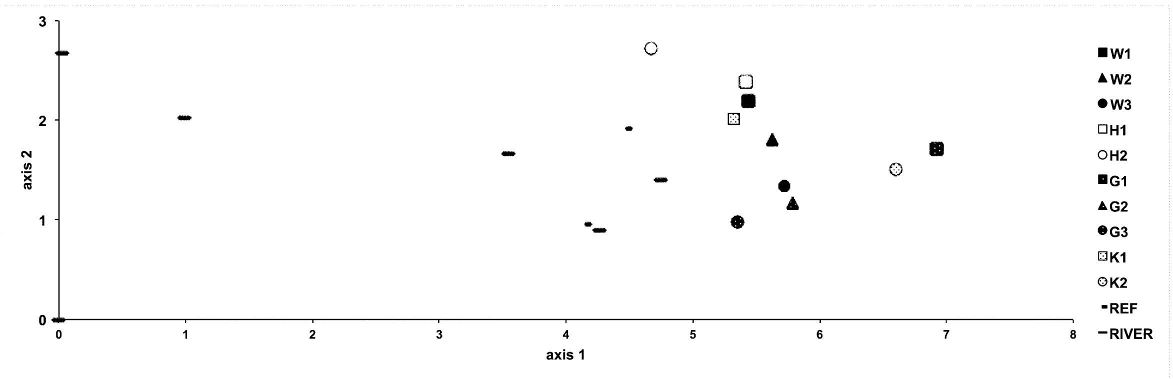


Figure 1: Detrended Correspondence Analysis ordination of the ground beetle (Carabidae) assemblages of the 10 sampling areas, two reference areas (perennial streams, Weißenbachlgraben) and six assemblages from an earlier study on the river banks in the National Park Gesäuse (FRITZE et al. 2007). Quadratic symbols: upstream sampling areas, round symbols: downstream areas, triangular symbols: areas of gravel mining. Black and dark grey symbols: valleys impacted by gravel mining. White and light grey symbols: control valleys. W...Weißenbachlgraben, H...Haindlkar, G...Gsenggraben, K...Kainzenalplgraben, REF...Reference areas (two downstream sampling areas in Weißenbachlgraben with perennial flow), RIVER...assemblage data from FRITZE et al. 2007).

The quality of the assemblages from the sites was (a) assessed as the number of individuals of threatened species and (b) as the percentage of the individuals of threatened species. Since no current Red Lists were available, the threat status assignment was based on personal experience and record count statistics from a personal faunistic database.

## Results

The sampling yielded 795 spider individuals of 30 species, 235 ground beetle individuals of 25 species, 190 rove beetle individuals of 11 species and 111 individuals of eight identified harvestmen, woodlice and millipede species. With 598 individuals, the wolf spider *Pardosa saturatior* was the dominant species of the assemblages. Among the ground beetle assemblages, *Bembidion cruciatum* was abundant in valleys modified by gravel mining. *Bembidion longipes* was less numerous and predominantly found in non-impacted valleys.

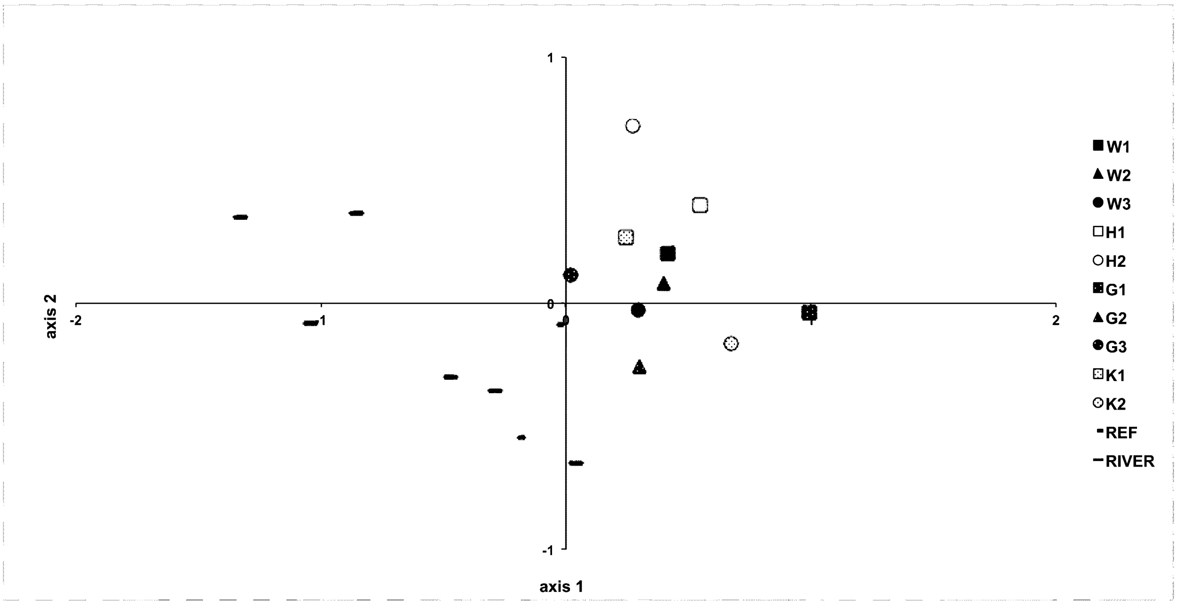


Figure 2: Nonmetric Mutidimensional Scaling ordination of the ground beetle (Carabidae) assemblages of the 10 sampling areas, two reference areas and six assemblages from an earlier study on the river banks in the National Park Gesäuse (FRITZE et al. 2007). Symbols as in Fig. 1.

Detrended Correspondence Analysis (Fig. 1) and Nonmetric Multidimensional Scaling (Fig. 2), two numerically different approaches to assemblage ordination, produced very similar plots for the ground beetle assemblages. Both plots showed a clear separation between ephemeral stream assemblages and perennial riverbank assemblages.

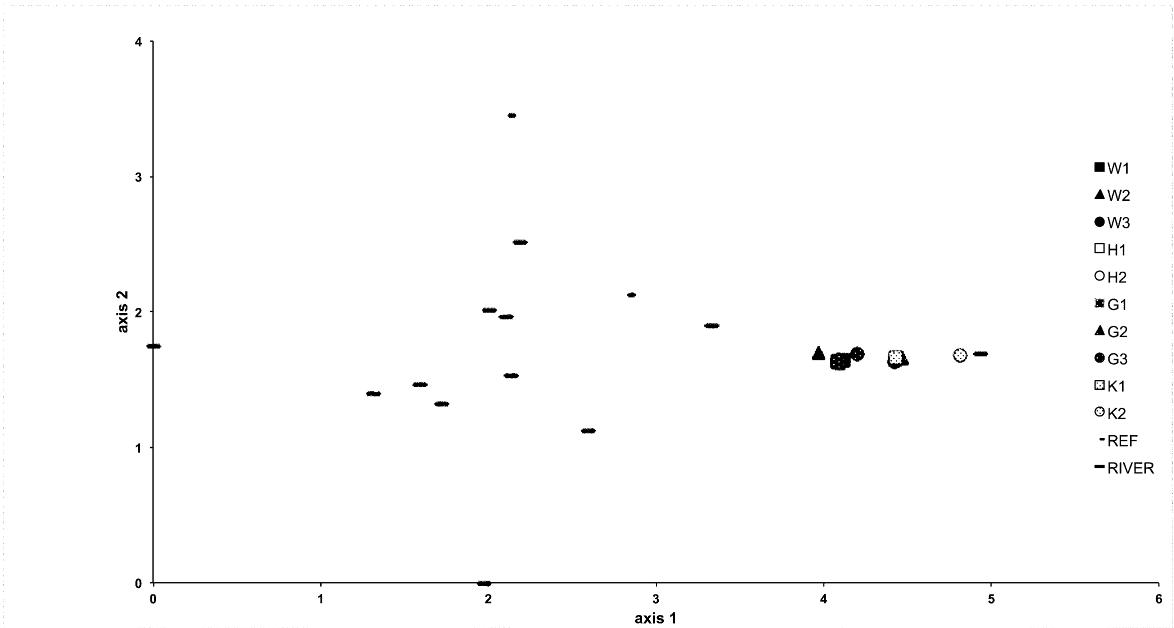


Figure 3: Detrended Correspondence Analysis ordination of the spider assemblages of the 10 sampling areas, two reference areas (perennial streams, Weißenbachlgraben) and 12 assemblages from an earlier study on the river banks in the National Park Gesäuse (BRANDL 2005). Symbols as in Fig. 1.

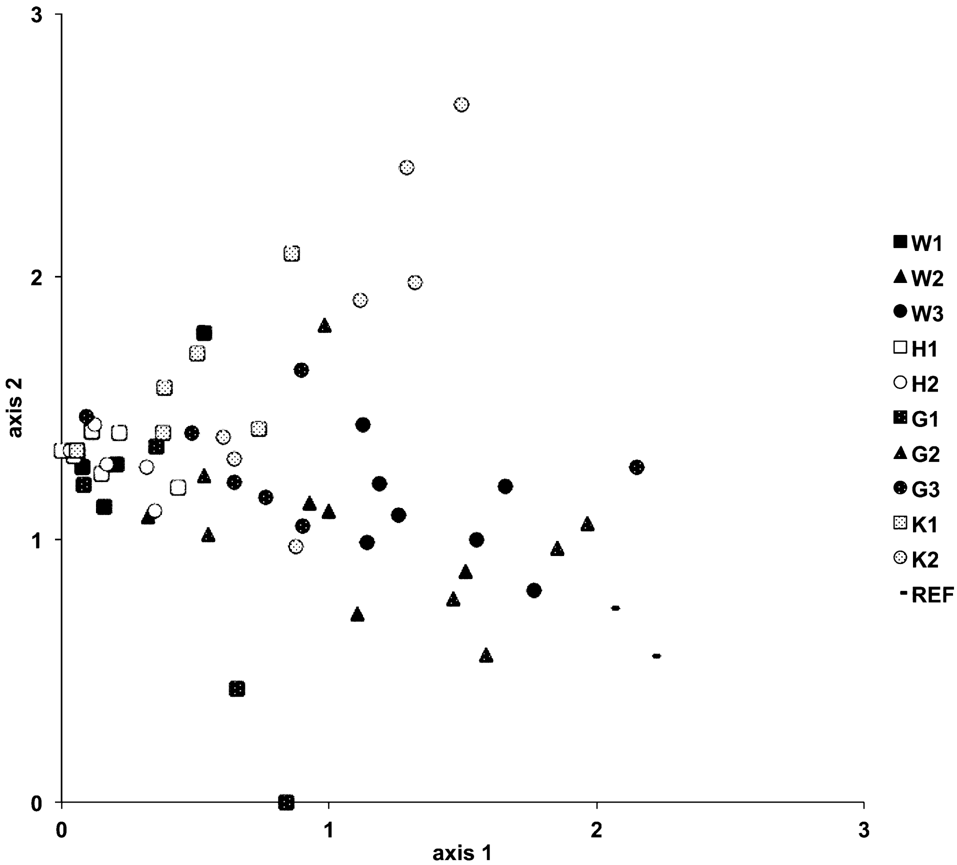


Figure 4: Detrended Correspondence Analysis ordination of the arthropod assemblages of all 70 samplings plus two reference samplings with perennial flow. Symbols as in Fig. 1.

Spider assemblages from riverbanks displayed considerably more variety than assemblages from the ten ephemeral stream sites (Fig. 3). The latter formed a closely packed cluster together with one of the assemblages from an earlierreference study (Langgrießgraben, BRANDL 2005). A multivariate assessment of all 70 sampling transects obtained in the present study (plus two reference samplings) based on all arthropod taxa revealed a high similarity of the upstream assemblages from all four valleys (left part of the plot, Fig. 4). Downstream assemblages show some differentiation between gravel mining impacted valleys and one of the control valleys characterised by several natural gravel banks (right part of the plot, Fig. 4). Assemblages from the downstream stretches impacted by gravel mining are similar to assemblages from the perennial reference sites.

Table 1: Individuals of threatened species in the ten sampling areas.

| Before-After | Impact Weißenbachlgraben | Control Haindlkar | Impact Gsenggraben | Control Kainzenalplgraben |
|---|---|---|---|---|
| Upstream | 65 | 99 | 44 | 58 |
| Mining Area | 48 | | 51 | |
| Downstream | 55 | 104 | 63 | 56 |

In most cases, sampling areas affected by gravel mining showed lower assemblage quality numbers than control areas, regardless whether assemblage quality was measures based on individuals of threatened species (Table 1) or based on their percentage in the total catch (Table 2). However, the differences were small and statistically insignificant both for individual numbers (ANOVA based on ln (x+1)-transformed values, $P = 0.57$ for the difference between Before and After, $P = 0.19$ for the difference between Control and Impact, $P = 0.76$ for the interaction term) and for percentages (ANOVA based on arcsin√-transformed values, $P = 0.18$ for the difference between Before and After, $P = 0.75$ for the difference between Control and Impact, $P = 0.53$ for the interaction term).

Table 2: Percentage individuals of threatened species in the total catch.

| Before-After | Impact Weißenbachlgraben | Control Haindlkar | Impact Gsenggraben | Control Kainzenalplgraben |
|---|---|---|---|---|
| Upstream | 90,3% | 91,7% | 53,1% | 60,9% |
| Mining Area | 58,0% | | 25,3% | |
| Downstream | 29,7% | 92,0% | 52,8% | 39,2% |

## Discussion

Mountain streams in debris-filled trough valleys may form a specific type of floodplain environment with extreme environmental conditions. To date, the study of the fauna of such floodplain environments seems to have been largely neglected. In the present investigation it became clear that gravel fields with ephemeral streams differ consistently form ordinary perennial river or stream banks in their ground beetle and spider assemblages. One reason for these differences is the dominance of *Pardosa saturatior,* a conspicuous large wolf spider that comprised large parts of the catch, particularly in upstream areas. Most identification keys on Central European spiders characterise *Pardosa wagleri* and *Pardosa saturatior* as sibling species, with *Pardosa saturatior* being larger and occurring in higher altitudes than *Pardosa wagleri,* typically above 1000 m. However, BUCHAR (1981) reports occurrences of *Pardosa saturatior*i n limestone scree at altitudes between 700 and 800 m in Tyrol and DAHL (1908) already characterised *Pardosa saturatior* as a species of ephemeral alpine torrents regardless of altitude.

The gravel mining had detectable influences on the arthropod assemblages, which was not only apparent from the qualitative assemblage comparison in the ordination plots, but also from the assemblage quality index numbers. However, a statistically significant reduction in assemblage index numbers was not detected. This may have several reasons. Firstly, replication at the treatment level was limited since only two impacted and two control valleys were compared, consequently, the statistical power of the test was limited as well. Secondly, local peculiarities of the valleys influenced the assemblage quality to a substantial degree. For example, narrow valley channels often led to spillover of trivial forest species, which reduced the assemblage quality index numbers. Thirdly, after the rainy period in July 2012, erosion processes re-created a runoff channel in one of the impacted valleys (Weißenbachlgraben) that approached the ecological conditions in the mining-impacted valley closer to those of the control valleys. Fourthly, even in valley stretches strongly transformed by the gravel mining, the typical and characteristic species of ephemeral gravel valleys were still present, albeit in lower proportions than in non-impacted valleys. This offers good prospects for the further development of the valleys, as debris reshuffling, erosion and sedimentation processes might restore the valleys to a more natural state over time.

## Conclusions

The transport of large amounts of scree and debris material is an important landscape-forming process in alpine regions. Protected areas allow the unfolding of such natural processes, even if they imply large-scale inundations and landscape transformation in the stream valleys. Ephemeral streams are side effects of debris accumulation in limestone mountain regions. They house species-poor yet specialised arthropod assemblages. The results of the present investigation highlight the need for a detailed investigation of the ecological and faunal consequences of natural landscape formation and erosion processes. In the valleys of the Gesäuse National Park, earlier impact from mining activities left traceable effects on the arthropod assemblages, but restoration to a fully natural state seems feasible.

## Acknowledgements

The study was commissioned and financed by National Park Gesäuse. Alexander Maringer supported the study with important background information, permits, map material, literature advice, critical feedback and constant support during all project stages.

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Zeitschrift/Journal: Nationalpark Hohe Tauern - Conference Volume

Jahr/Year: 2013

Band/Volume: 5



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Artikel/Article: Effects of gravel mining on the surface-active arthropod fauna of ephemeral gravel-bed stream valleys in the National Park Gesäuse (Styria, Austria) 843-848